KELP FOREST MONITORING DESIGN REVIEW

Technical Report CHIS-96-01

Channel Islands National Park, California

Gary E. Davis, Daniel V. Richards, David Kushner

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Summary

The National Park Service initiated an ecological monitoring program in 1981 to determine the health of kelp forests in Channel Islands National Park, California. This program seeks to establish the normal limits of variation of population parameters, to provide early warnings of abnormal conditions, and to identify possible agents of abnormal change. We formally reviewed this kelp forest monitoring program (KFM) in 1995 to improve the quality and application of the information it produces. In August 1994, we contracted with the firm *Ecometrics* for a temporal trends analysis of the 1982 through 1993 kelp forest monitoring data to determine the power of these data to resolve inter-annual and inter-site differences. The final report was received in December, 1994. Paul Geissler, National Biological Service, provided additional analysis during a review of the entire Channel Islands National Park ecological monitoring program in June, 1995. Among other useful comments, he suggested using control tables to scan the data-base for anomalous events. In September, 1995, we held a workshop with biologists, statisticians, and managers experienced in long-term ecological studies and coastal ecosystem monitoring. We asked them to evaluate these analyses and to apply their expertise to improving the program. The workshop goals were: (1) to evaluate performance of the National Park Service Kelp Forest Monitoring Protocol, and (2) to recommend changes in the Protocol to improve accuracy, precision, and applicability of the information generated by the monitoring program. Recommendations from the workshop were reviewed by the Channel Islands Marine Science

Committee, a multi-agency and university group of scientists and managers who have guided development and operation of the kelp forest monitoring program since its inception in 1981. This report describes the evaluation process and the recommended changes in the protocol. A revised peer-reviewed protocol will be produced as the final product of this evaluation.

Introduction

Purpose of Monitoring

Why monitor park resources? Why spend the time and money to determine the condition of plant and animal populations in a national park? They are already ‘protected’. Unfortunately, habitat and population fragmentation, unsustainable exploitation, invasions of alien species, and pollution threaten the integrity of park ecosystems across America (Halvorson and Davis 1996). Parks are not isolated, independent, elements of the land/seascape, but rather integral parts of the whole biosphere. Park managers must convince others to protect and preserve parks. Parks can not be ‘saved’ alone, and the National Park Service alone can not save the parks. The required collaboration requires more factual information about ecosystem health and dynamics than the belief-based management of the early 20th century that produced predator control, fire suppression, and other ill-advised resource stewardship practices in parks.

Monitoring is needed to determine ecosystem health. A healthy ecosystem is one in which all components of the system are intact (not missing species or processes, like fire), it is alien-free (no extra species), its vital sign parameters are within normal limits of variation, and trends in those parameters do not threaten system integrity. Measurements and predictions of ecosystem health are needed to understand system structure and function, and to facilitate effective management. Since vital signs and their dynamics are virtually unknown for kelp forests, monitoring is needed to measure variation in parameters posed as ecosystem vital signs (population dynamics of selected species) in order to determine normal limits. Monitoring these population parameters will permit diagnosis of abnormal conditions in time to develop and employ mitigation strategies. For example, monitoring California brown pelican reproduction identified DDT contamination early enough to remove it from the food chain, before the adult bird population collapsed and its reproductive capacity was irreparably lost. Finally, monitoring information must be able to identify potential agents of abnormal change to help frame research hypotheses for investigations of causality and potential treatment efficacy.

Program History

The process used to design the kelp forest monitoring program is described in a detailed step-down diagram by Davis (1989). It was a three-step process, starting with a conceptual model, followed by design studies, and an implementation phase. Thirty-six scientists at a workshop at the Marine Science Institute at the University of California, Santa Barbara, in January 1981, articulated a conceptual model of park kelp forest ecosystems. Workshop participants developed selection criteria that assured a representative sample of locations in the park and kelp forest species, including those of concern to management agencies. They also nominated sites, species, and sampling techniques for long-term monitoring. A Steering Committee, composed of scientists and managers from the California Department of Fish & Game and National Park Service reviewed the workshop nominations, independently applied the criteria, and conducted field surveys in March, 1981 to select sites and test techniques. A design team, headed by G. E. Davis, selected and established sites in August-September 1981, and then tested and modified sampling designs from 1982 through 1986 (Davis 1985). The National Park Service published the protocol (Davis, 1988) and implemented the program in 1987.

Design Considerations

The 16 selected sites represent the range of biogeographical and physical settings of kelp forests in Channel Islands National Park. There are at least two sites in each of the six recognized zones of the Californian, Oregonian, and Transition biogeographical regions, both north and south of the islands. From a list of nearly 1,000 species, 68 taxa that met these criteria and that can be positively identified in the field were selected for monitoring. The selected species-array represents all macroscopic trophic levels of park kelp forests, and includes endemics, aliens, species with special legal status, exploited species, common species, those that provide structural elements to the forest, like *Macrocystis*, and heroic or charismatic species of general public interest. Sampling schemes were adapted to fit species size, mobility, and distribution, based on preliminary samples taken during the design phase. They include quadrats, band-transects, random point contacts, visual fish transects, size frequency surveys, thermographs, video surveys, photogrammetric plots, and species inventory surveys. Accuracy and precision goals were set by park managers to resolve 40% changes in mean values, with $\alpha=0.05$ and $\beta=0.20$ (A type 1 error (α) means erroneously reporting that a parameter changed when it really did not, and a type 2 error (β) is not detecting a change when it occurs. Probabilities are typically set at 5% and 20% because a false report is considered to be much more serious than failing to detect a change). The protocol specifies the number, distribution, and size of plots or samples required for each technique (Davis 1988).

Monitoring Applications

Information from the monitoring program has been used to address several major resource issues in Channel Islands National Park and the surrounding region. It was used to evaluate the efficacy of removing alien species, such as European hares on Santa Barbara Island and feral pigs on Santa Rosa Island. Over the last ten years, monitoring information was instrumental in a series of management decisions to reduce unsustainable exploitation, protect brood stock, and restore populations of black, pink, green, and white abalones (Davis et al. 1989, Haaker et al. 1989, Richards and Davis 1993, State of California 1995). The park's abalone population data were virtually the only long-term fishery-independent information available and used by the State of California to close black, pink, green, and white abalone fisheries statewide in a recent effort to protect future abalone fisheries productivity.

The monitoring program has also helped develop better ecological assessment tools by testing standard techniques and by developing new approaches. Kelp forest fish populations are notoriously difficult to assess. Davis and Anderson (1989) compared traditional transect-based fish counts with video and baited stations, and tested accuracy of these techniques by employing a novel marine electro-shocking device to produce mark-recapture population estimates at discrete study sites. Juvenile recruitment dynamics provide early warnings of population collapses, but are difficult to measure in marine systems. The kelp forest monitoring program facilitated development of an artificial recruitment module (ARM) that allows quantitative assessments of cryptic juvenile recruitment without destroying native habitats (Davis 1995).

Evaluation Process

The program evaluation process involved four steps: analysis of historic data, a workshop discussion of results and options, review by the program steering committee, and protocol revision by park staff. The *Ecometrics* analysis (Schroeter et al. 1994) provided temporal trends power analyses for 68 kelp forest taxa, at 16 sites, for 12 years (1982-1993). The results of these analyses included indications of the degree of confidence to detect change in the densities (abundance) of each species (e.g., percent of mean) at each site, and the ability of the data-set to detect cohorts and annual cohort strength from size frequency data. The results of this analysis, a copy of the protocol, and the goals of the program evaluation, were sent to participants several weeks prior to the September 19-20, 1995 workshop. Paul Geissler's analysis was also shared with participants during the workshop (National Biological Service 1995).

Summary of **Ecometrics** *Analysis*

The power analysis indicated that the protocol (Davis 1988) provides generally good power to detect differences between locations in the abundance of benthic organisms which occur at relatively high densities. Nevertheless, many organisms are uncommon at many locations. As a result, we can detect a significant difference of 80% or greater in only a small proportion of the many possible comparisons among sites and years. Therefore, most pair-wise comparisons, for which power is at least 80%, can only detect differences greater than 60% of the mean.

Fishes presented a more difficult sampling situation. The current visual transects provide very low power to detect differences in abundance between locations or surveys, because there are only two replicates per location each year. There is also very little power to detect temporal trends in the average abundance of species because of the small numbers of samples. The spatial replicates used to determine a within-site means can not be used in these trends analyses, so the annual means become the replicates. Therefore, the maximum sample size for temporal trends analysis was only 13.

In general, the number of individuals measured for size frequency distributions at each site is too small to allow accurate, site-specific, estimates of annual cohorts. Occasionally a mode is present that can be interpreted as recruits of the previous year or two. Nevertheless, there were only a few cases where the modes remained sufficiently well-defined to allow estimates of growth or mortality.

Specific comments and recommendations for improving the KFM protocol:

- Modify size categories for macroalgae so that young-of-the-year can be distinguished from older individuals
- Use larger quadrats for macroalgae and other organisms that have low densities
- Turn rocks and move large urchins to count small individuals occurring within the spine canopy
- Include all motile species now counted in band transects in these invasive samples
- Precision increases slowly after around 10 replicates for species such as bat stars, purple sea urchins and sea cucumbers
- Conduct a cost-benefit analysis to determine if some of the effort expended on replicate quadrat counts might better be used for other tasks
- Count small cryptic invertebrates in two size categories, and in invasively sampled 1-m^2 quadrats
- Select two random points within each of 12 strata instead of censusing two contiguous band-transects
- Define purpose of the data better
- Insure that the sampled "point" is very small in RPCs
- Randomly and independently place RPC points

- Spend less effort on estimating percent cover by reducing number of RPC replicates from 25 to 10
- Census fish transects only once per day, and increase number of days
- Randomize starting point for size frequency surveys, and use a 2-m stick to maintain orientation

Workshop Results

After introducing the participants, Table 1, and reviewing the evaluation goals and workshop agenda, we brainstormed topics for discussion to develop improved sampling, analytical , and reporting procedures, and to improve the kelp forest monitoring protocol. The topics identified for discussion at the beginning of the workshop fell into two categories, sampling procedures or data management and utilization. They are indicated below.

<u>Sampling Procedures</u>

Abalones
Fishes
Macrocystis (giant kelp)
Photogrammetric plots
ARMs vs. invasive and destructive techniques
Size frequency surveys
Criteria for species selection
Species check-list, biodiversity survey
Fixed *vs* Variable plots
Random Point Contact (RPC) for percent cover
Observer variation
Qualitative observations
Criteria for changing protocol
Relative cost of monitoring techniques
Gradient analysis of site selection
How to ensure continuity

<u>Data Management /Utilization</u>

How to effect data management/integration
How to find out who uses the data
How are results used by park managers and others
Analysis frequencies -5 yrs. Why not annually?
Accuracy, Precision, & Power
Report format/distribution
Current reports to detailed and not enough detail
Cumulative trends graphs
Policy-level analysis
Interpretive/Education applications
Develop more products e.g. oral/visual presentation at Visitors Center
Integration with other programs

Mia Tegner, Scripps Institute of Oceanography, summarized the consensus of the workshop discussion regarding the program and these specific topics. She indicated that monitoring used to be considered a non-academic endeavor, not worthy of serious scientists, but that now it is regarded as acceptable science, even necessary for understanding ecosystems in order to frame good experimental designs. The Channel Islands National Park Kelp Forest Monitoring Program is recognized as a leader in this field. It is a good program that can be made better through this review and evaluation. University of California, Santa Barbara, statistician Allan Stewart-Oaten was emphatic: "don't change anything, this continuous long-term data set is exceedingly valuable, even if somewhat flawed." Any changes should be considered carefully. Most importantly, park managers need to review the level of changes they feel they need to be able to detect, and that they use to trigger management decisions. The levels of change that need to be detected and the kinds of uses for the information will help scientists decide how to modify the protocol to better meet managers' needs. The workshop discussion yielded the following list of suggestions and comments regarding the current protocol that were considered by the Channel Islands Marine Science Committee in making their recommendations about protocol revisions.

Fish Sampling

- Fish density may be a fluctuating symmetry index (TREE article Barry Noon)
- Add size estimates to abundance counts (Colin Buxton)
- Transect rules require that counted organisms do not respond to observers
- Use video transects to reduce observer variation
- Use video transects on different tracts
- Increase sample size (number of samples)
- Try to apply data to a specific issue and see if it works (Steve Murray)
- Increase spatial replicates and decrease transect size to increase sample size for more power

Benthic Sampling

- Sample only suitable habitat

- Add destructive habitat sampling to augment density counts and size frequency data, invasive sampling is needed for urchins
- Sample enough quadrats to include 100 individuals to measure population structure
- Revise and clarify size frequency sampling instructions
- Improve site descriptions and include a history of site selection
- Evaluate photogrammetric plots to see if they could replace the quadrat and RPC samples
- Replace *in situ* RPCs with vertical video
- Increase plot size for adult *Macrocystis* to 100 m^2; continue counting juveniles in quadrats
- Use stipe counts as a surrogate for plant size, do not bother with holdfast measurements
- Improve definition of juvenile kelps, haptera above primary dichotomy identify adult *Macrocystis*
- Algae are under-represented in the protocol, add species with video transects
- Enhance size frequency data to better detect recruitment events
- Collect more demographic data on kelps
- Evaluate photogrammetric plots vs. quadrat and RPC counts
- Count all band-transect species in quadrats too
- Add a band-transect along the reference transect for *Macrocystis*
- Consider using fixed plots rather than stratified random plots to reduce within site variation
- Sub-divide quadrats into 1/4's for numerous species
- Collect microcrustaceans and archive samples for future potential analysis

Analytical Procedures

- Report physical data collected, i.e., visibility and sea temperature

- Document data entry procedures better
- Plot data to find outliers
- Look for ways to ease data access for others
- Standardize codes so that no special knowledge is required to interpret data base
- Explore decision theory to relate uncertainty to variability in populations
- Explore appropriate models to use in evaluating change, e.g., pair-wise may not be appropriate

Design Considerations

- Protocol changes need not be all or nothing, but may be slight changes
- Re-examine species selection and explicitly describe original criteria
- Develop criteria to adjust sampling strategies when species abundance and distributions change
- Re-examine focus on abundance, density, and distribution and consider other population parameters, e.g., spacing among individuals, growth and mortality rates
- Provide an explicit framework to show how monitoring data are applied to management issues

Channel Islands Marine Science Committee Recommendations

After additional discussion of the workshop recommendations, the Marine Science Committee identified the following as the most desirable changes to the protocol. Further compromises may be necessary, after cost-benefit analyses are performed.

General Handbook Content & Format

1. Increase detail of site descriptions, e.g., describe current uses and regulations at each site, and provide perspective drawings of each site
2. Provide a history of site selection process and each site
3. Describe species selection criteria and their application that yielded the current list (especially the algae and the problems of positive field identification)
4. Describe desired level of detection for changes
5. Define purpose of monitoring program
6. Describe potential and actual uses of data, i.e., how monitoring data are applied
7. Document data entry procedures
8. Standardize codes to ensure that no special knowledge is required to interpret data sets, i.e., improve metadata

Annual Reports

1. Report physical data, e.g., visibility & temperature, in the Annual Observation Report
2. Add a second annual report called an Annual Trend Report that provides context for annual observations, identifies trends, and documents frequencies of extreme events-summarize data by ecological zones and compare annual observations with previous years

Sampling Techniques

1. Quadrats, RPCs, and Band Transects
   a) Add demographic data on *Macrocystis*, *Allopora*, and gorgonians by marking individuals and

defining size categories

b) Add all species currently sampled on band transects to quadrat samples

c) Count juvenile brown algae on quadrats (single blade (*Eisenia*, *Pterygophora*) or less than 1 m tall (*Macrocystis*) or <10cm wide (*Laminaria*))

d) Add new protocol using 40 1x5 m quadrats along length of transect to count adult kelps and subadult *Macrocystis* (>1 m tall with no haptera above primary dichotomy)

e) Re-mark quadrat frames (tape at midpoint) to indicate 1/4 m^2 to facilitate counting extremely high urchin densities

f) Abalone-search until one is located and measure density from that point, leave in band transect samples

g) Reduce the number of quadrats, from 20 to 12, and RPC plots, from 25 to 15, as necessary to increase sampling effort with other techniques

2. Size Frequency Distributions

a) Clarify that the purpose of collecting size frequency data is primarily to detect and quantify recruitment events, not to calculate growth and mortality rates

b) Add fish size estimates

c) Add Artificial Recruitment Modules (ARM) - 7 per site, and modify ARMs to reduce height from 5 to 3 layers, to provide ≈100 m^2 of crevice habitat at each site

d) Revise and clarify size frequency data collection instructions.

3. Fish

a) Change counts along 100 m reference transect to 4 50 X 2m transects over unique ground with each 50 m transect conducted in 2.5 minutes; species split between two observers, one observer for demersal species and the other for actively swimming or schooling species; four transects at each site on two days at least two weeks apart will describe both within and between day variation.

b) Add estimates of individual fish sizes to transect counts by carrying fish silhouettes (30 cm & 10 cm) on 1 meter rods for size reference

c) Add timed-species counts following the Great American Fish Count protocol, with six counts at each site on two days at least two weeks apart

Research Needed to Improve the Kelp Forest Monitoring Program

KFM Protocol Modifications

1. Calibrate ARMs to natural habitat (conduct outside park and sanctuary)
2. Replace *in situ* RPCs with videogrammetric transects (underwater 'aerial' images) and remote sensing automated image processing
3. Decision theory - relate uncertainty to variability in populations, and provide an explicit framework showing how monitoring generated data are applied to management issues
4. What are appropriate models to use in evaluating change, e.g., pair-wise comparisons may not be appropriate, while trends, moving averages and other time-series analyses may provide better descriptions of the system

Data-Base Analyses

1. Determine which species in KFM protocol have paid off and provided most "bang for the buck"
2. Divide data into time blocks relative to El Niño to evaluate effects of natural extreme events
3. Compare sex ratio of sheephead in protected and unprotected areas to evaluate effects of fishing and effective size of refugia
4. Describe recruitment dynamics to evaluate assumptions of surplus yield fishery management paradigm
5. Compare population and community dynamics of protected and harvested sites
6. Explore data screening technologies with Paul Geissler (NBS)
7. Analyze ecological zone affinities & differences with Paul Geissler (NBS)
8. Evaluate photogrammetric plots by comparing presence/absence in photos with quadrat and RPC data.
9. Evaluate ARM ability to detect recruitment events

Conclusions

The program review provided a realistic perspective on the strengths and weaknesses of the protocol. It is apparent that several aspects of the protocol can be strengthened with minor changes, keeping in mind Stewart-Oaten’s admonishment “not to change anything.” However, changes in abundance and distribution of target species, such as abalone, in knowledge of long-term variation of measured parameters, and in technology all contribute to the need for some changes. The park staff, with advice from the resident National Biological Service research marine biologist, will now draft a revised protocol that contains an appendix documenting changes in the protocol and providing a history of changes for interpreting the long-term data base. Workshop participants will be sent a copy of the draft revised protocol for comment.

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Tables

Table 1. List of participants

Name	Address	Phone/e-mail
Colin Buxton	Faculty of Fisheries & Marine Environment Australian Maritime College PO Box 21, Beaconsfield 7270, Tasmania	Phone: 003-354444 Fax: 003-354459 c.buxton@fme.amc.edu.au
Mark Carr	Coastal Research CTR Marine Science Inst. UC Santa Barbara, CA 93106	(805) 893-3104 carr@lifesci.ucsb.edu
Gary E. Davis	National Biological Service 1901 Spinnaker Dr Ventura, CA 93001	(805) 658-5707 gary_davis@nps.gov
John Dixon	Ecometrics 2270 Camino Vido Roble #L Carlsbad, CA 92009	(619) 438-5953
Alvaro Dominguez	3957 Foothill Rd Santa Barbara, CA 93110	(805) 687-0313 udomia00@mcl.mcl.ucsb.edu
Jenny Dugan	Marine Science Institute University of California at Santa Barbara Santa Barbara, CA 93106	(805) 893-2675 j_dugan@lifesci.ucsb.edu
Jack Engle	Marine Science Institute University of California at Santa Barbara Santa Barbara, CA 93106	(805) 893-8547 j_engle@lifesci.ucsb.edu
Laura Gorodezky	Channel Islands National Marine Sanctuary 113 Harbor Way Santa Barbara, CA 93109-2315	(805) 966-7107 educinms@rain.org
Pete Haaker	California Department of Fish & Game 330 Golden Shore Suite 50 Long Beach, CA 90802	(310) 590-5109 75372.3706@compuserve.com
David Kushner	Channel Islands National Park 1901 Spinnaker Dr . Ventura, CA 93001	(805) 658-5773 david_kushner@nps.gov
Derek Lerma	Channel Islands National Park 1901 Spinnaker Dr . Ventura, CA 93001	(805) 658-5771 derek_lerma@nps.gov

Deborah McArdle	University of California, Sea Grant	(805) 882-1889 damcardle@ucdavis.edu	
Kathryn McEachern	National Biological Service 1901 Spinnaker Dr Ventura, CA 93001	(805) 658-5753 kathyrn_mceachern@nps.gov	
Jeff Mondragon	Department of Biological Sciences Humboldt State University Arcata, CA 95521	(707) 668-4025 jem1@axe.humboldt.edu	
Steve Murray	Department of Biological Sciences Cal State University Fullerton Fullerton, CA 92634	(714) 449-7291 smurray@fullerton.edu	
Barry Noon	National Biological Service 1849 C St N Washington, DC	(707) 822-3691 barry_noon@nbs.gov	(202) 482-3979 abbie12@aol.com
Dan Reed	Marine Science Institute University of California at Santa Barbara Santa Barbara, CA 93106	(805) 893-8363 reed@lifesci.ucsb.edu	
Dan Richards	Channel Islands National Park 1901 Spinnaker Dr Ventura, CA 93001	(805) 658-5760 dan_richards@nps.gov	
Leonard Robbins	CPSU University of Arizona	(520) 621-1174 len@nexus.srnr.arizona.edu	
Steve Schroeter	Ecometrics 2270 Camino Vido Roble #L Carlsbad, CA 92009	(619) 438-5953 schroeter@rohan.sdsu.edu	
Allan Stewart-Oaten	Dept of Ecology, Evolution, & Marine Biology University of California at Santa Barbara Santa Barbara, CA 93106	(805) 893-3696 stewart@lifesci.ucsb.edu	
Ian Taniguchi	Caifornia Department of Fish & Game 330 Golden Shore Suite 50 Long Beach, CA 90802	(310) 590-4825 75372.3706@compuserve.com	
Mia Tegner	Scripps Institute of Oceanography University of California at San Diego La Jolla, CA 92093-0201	(619) 534-2050 mtegner@ucsd.edu	
Lyman Thorsteinson	National Biological Service Western Regional Office 909 First Ave, Suite 800	(206) 220-4614 lyman_thorsteinson@nbs.gov	